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THE EFFECT OF MOVEMENT IN THE CUE DIMENSION ON A VISUAL SEARCH TASK

by

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A THESIS

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THE FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled "The Effect of Movement in the Cue Dimension on a Visual Search Task" submitted by Edmund James Welland in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

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ABSTRACT

The purpose of this study was to examine the effect of movement in the cue dimension on performance of a visual search task. There were three factors of experimental interest; movement speed, density, and size of the non-target set. The task required the subject to locate, identify, and mark four target items presented in a visual display. The dependent variable, search time, was the time required to locate and mark the four targets presented on each trial.

The design for the primary analysis was a treatment by subjects, factorial, complete block, mixed model with repeated measures. A five way analysis of variance was computed. The test on means used was Duncan's New Multiple Range Test. A secondary analysis was completed for search times under similar non-target item conditions only. A four way analysis of variance was computed. The test on means used was Duncan's New Multiple Range Test.

It was concluded that slow movement speed of display items caused an increase in visual search time under (1) conditions of high display density and (2) conditions of non-similar background. The effect of increasing the display density caused an increase in search times irrespective of movement or background conditions employed in the study. In addition, increasing the size of the non-target set had its greatest effect when viewed as an interaction affected by increases in item density and slow movement speed.

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CHAPTER I

INTRODUCTION

Many of the objectives of Physical Education are achieved through the participation of individuals in activity orientated programs. Participation implies performance, which suggests the need for physical educators to understand the basic components of performance. Human performance theory as outlined by Fitts and Posner (1967) offers one approach to such an understanding. They present a view of complex skills as being composed of relatively basic components. It is through an understanding of man's limitations within these basic components that the instructor can attempt to structure the activity situation to provide for optimal performances by the participants.

In most activities relevant to Physical Education, the skill takes place in an environment that is constantly changing or has dynamic qualities. Optimal performance is partially dependent on the ability of the performer to acquire information from the environment relevant to the task being performed. The selection of information from the environment could be considered the first step in the production or creation of a performance.

The selection of environmental information occurs through many modes, e.g. visual, auditory, and kinesthetic. Selection of information through the visual input mode is

the major topic area of this experiment. Visual selection of information has been classified generally as visual search in the literature reviewed.

Definition of Visual Search

Visual search is initiated when the information (targets) required in a visual display are not immediately available. Egreth (1967) described visual search as a task requiring the subject to locate a specific stimulus (target) or set of stimuli contained in an array of stimuli (non-targets). Forsman (1967) defined visual search as a repetitive, sequential discrimination problem performed under a speed demand.

Williams (1966) partitioned the visual search act into two components, identification, and acquisition. Identification implied the recognition or classification of the foveally imaged objects as targets or non-targets. Acquisition involved the selection of the information outside the foveal area on which to fixate next. Thomas and Lansdown (1963) suggested that visual search involved foveal focusing and foveal fixation. They classified the fixation as the perceptual part of the act.

The constant concept underlying these definitions of visual search is that it is an activity on the part of the subject, selecting and testing objects in the visual display in terms of the target specifications.

Evidence of Visual Search as an Heuristic Process

The operational definition of visual search found in the search of the literature implied an heuristic activity on the part of the subject searching for the targets. Support for visual search as an activity is found in many articles reporting eye movement data on visual search tasks.

Enoch(1960) found evidence that supported a two phase visual search process. The first was an orientation phase which remained relatively stable for each individual subject. The pattern of this initial phase also remained stable for various display variables. Familiarity of the material in the display was the only variable found that influenced this phase. The effect was that the orientation phase was shortened in length of time.

The second phase was a specific search phase. Cues which would aid in locating the target were utilized immediately upon initiation of this phase. During this phase, a marked non-uniformity of coverage occurred at the centre of the display with less in the peripheral regions. This result was general to most displays. Enoch concluded that the general path of search was controlled by the central nervous system. The individual eye movements within the general search pattern were dominated by the effects of peripheral retinal stimulation.

Baker (1967) investigated search performance on three types of radar screen monitors. The reported results of the

experiment support a monitor system which constrains the search process to the areas of highest probability of detection, thereby eliminating eye fixations in areas of low target probability.

A study by Neisser and Stoper (1965) reported the effect of attempting to redirect the search process. Cue words were inserted in the text being scanned which indicated the absence of the target in the following fifteen or five lines. The subjects were reported to use the cue words to effectively reduce search time.

Ellis (1968) used a system of indicators to modify the search strategy of his subjects. He reported that through the use of free search within specific restraints, highly effective search performance was obtained.

In conclusion, the evidence from studies of visual search imply that search is heuristic in nature and thereby affected by variables related to the strategy selected by the subject.

A Classification of Variables Affecting the Search Process

Toward the goal of classification of the available results from completed search studies, the following three categories are suggested as being useful from research as well as application aspects.

1. Display Variables.

The variables assigned to the first category were those whose effect is inherent in the structure and composition of

the visual display. Variables such as display density (number of items in the display), target non-target similarity, degree of homogeneity of non-target items, orientation of items, structure within the display (degree of spatial organization), and the size and shape of the display are examples within this category. A more extensive review of the display variables relevant to this study will be presented in Chapter II.

2. Performer Variables

The second category was defined as variables which are associated with the state of the performer. One variable could be specified as the amount of experience or the phase of learning associated with the performer.

Stern and Bynum (1970) analysed the visual search behaviour of novice and skilled helicopter pilots. In general, they found a significant difference in the search performance of the two groups. The skilled pilots spent a significantly greater proportion of flight time actively searching the environment during a cross country flight than did the novice pilots.

Thomas and Lansdown (1963) investigated the visual search patterns of radiologists in training. One subject constantly exhibited better search performance than the other subjects. Upon further investigation, it was found that he had spent three years as an x-ray technician before entering medicine.

A second example considered was age of the subject. Two experimental conditions involving visual search for a target letter in two levels of background confusability (low signal to noise ratio) were investigated by Gibson and Yonas (1966). The four groups of subjects were selected from age levels ranging from Grade Two students to University sophmores. The grade differences (ages) were significant in both conditions. The significantly faster search times of the older subjects supported the hypothesis that quantitative changes occurred in the process underlying visual search through development. The lack of significant age by condition interactions failed to support the hypothesis that qualitative changes occurred during development.

Forsman (1967) reported that increases in chronological age were related to decreases in search time. The task involved searching for targets of varying complexity (based on the number of angles enclosed by the target form). The complexity had a greater effect on the younger subjects than on older subjects. The qualitative difference may, however, have been confounded with learning, as the subjects had two seconds to view the target before the timing of the search act was initiated.

A third performer variable was classified as the achievement level as measured by the educational success of the subject. A study by Rosenberg (1961) compared the performance of two groups of retarded subjects on a visual search task. The range of I.Q.s for the former group was

35 to 37, while the I.Q. range for the latter group was 56 to 89. Different nonsense geometric shapes were placed in each cell of a 36 cell matrix. The target shape was randomly selected from the set of 36 for each trial. The two exposure conditions of the targets prior to each trial were four seconds and continuous exposure. The same matrix was used on each trial. Rosenberg reported that the lowest I.Q. group was significantly poorer on the task under both stimulus exposure conditions. No interactions were reported as significant.

Spivack (1963) questioned Rosenberg's constant presentation of the same search matrix (visual display) on each trial. He suggested the presence of an incidental learning situation which would confound the perceptual nature of the task. He also questioned the possibility of a differential effect of the speed set (four second exposure condition).

Welland (1969) compared the visual search behaviour of retarded subjects with subjects of high academic achievement. Both groups were similar in age. The search task involved background density and background similarity. The above average group exhibited significant changes in the speed parameter across the density factor. No significant change was found in the accuracy of this group under any of the four experimental conditions. The below average group exhibited significant changes in both speed (search time) and accuracy (omission and commission errors). The findings were used as support for the hypothesis that qualitative differences as

well as quantitative differences existed between the two achievement groups on a visual search task.

3. Task Variables.

The variables assigned to the third category were associated with the specific requirements of the search task. Arnoult (1960) proposed three types of tasks common to the general area of visual search. The first class of task was classified as discrimination tasks in which the subject responds to a change in the display with the response, same or different. The second class of task involved recognition in which the subject responds by stating the target as the same as a standard. The third class of task was designated as identification in which the subject responds by classifying the target. Arnould's proposed classification appeared to involve increasingly complex cognitive activity underlying the search process.

A second variable assigned to this category was the size of the target set. A series of studies by Kaplan and Carvellas (1965), Kaplan, Carvellas and Metlay (1966), and Metlay, Sokoloff and Kaplan (1970) reported a significant increase in search time as the size of the target set (number of possible targets) increased.

A third classification of task was reported by Neisser (1963). He concluded that search times were significantly longer for tasks involving search for the absence of a target than for the presence of a target. Eriksen and Collins

(1969), and Brown and Chick (1970) reported similar results. Neisser and Beller (1965) investigated the effect of target specification on the search process. The search performance through work lists for targets belonging in a large non-specific class (e.g. animals) was significantly slower than for targets belonging to a smaller more specific class (e.g. days of the week).

In summary, to fully understand a specific search performance, factors involved in the composition of the visual display, factors describing the state of the performer, and the factors involved in the actual task should be considered.

Statement of the Problem

The vast majority of studies investigating aspects of the visual search process reviewed by the author have used visual displays in which the display items have been static. The visual displays relevant to activities in the realm of Physical Education, however, would appear to be dynamic in the sense that some or all of the display items are moving.

The proposed direction of further research is to ascertain the main and interacting effects of variables, whose effect on search performance has been documented for static displays, in displays containing dynamic qualities.

The study introduced one element of motion into a static display. This element was that of movement within the cue dimension. Thus, movement was introduced across the orientation factor of the display and was manifested as item

rotation. The particular advantage of this study in terms of practicality was that the spatial location of the items remained constant throughout the display, thus eliminating the need for elaborate eye movement recordings for performance analysis.

The second factor investigated was that of display density (item numerosity). The effect of display density was found to be a significant factor in all studies using static displays.

The third factor utilized, concerned the effect of the non-target items in the display. The primary aspect investigated was the effect of a non-target set consisting of one non-target shape (similar background) and a non-target set consisting of four non-target shapes (non-similar background). The secondary aspect investigated was the target non-target similarity.

The study analysed visual search performance across two levels of density, two levels of non-target similarity, four levels of target non-target similarity, and three levels of movement speed.

Assumptions

The study was organized to compare the input efficiency of the human operator across several visual search displays. The total test involved all three components of human performance; input, processing, and output. The altering of the experimental factors (density, non-target sets, and speed of

movement) was assumed to result in changes only relative to the input operation of the human performer.

It was further assumed that the visual search task employed held the task and state of the performer variables reasonably constant. To further this assumption, the target shape was constant for all experimental conditions. In addition, a relatively homogeneous group of subjects was employed for the study.

The timing mechanism used for the measurement of the dependent variable (search time) was initiated by the experimenter on each trial. It was assumed that the variations in the experimenter's reaction time would not constitute a form of bias toward any of the experimental conditions in the study.

Delimitations

The study investigated one aspect of movement in a dynamic visual display, that of movement in the cue dimension (item rotation). The cues available for item discrimination were restricted to one dimension shape. Other dimensions such as colour and size were held constant throughout all experimental conditions.

Limitations

The investigator initiated the timing mechanism at the start of each trial. The variations of search times for the first target was partially due to fluctuations within the reaction time of the investigator.

The size of the display items and the area of the visual display were constant for all experimental conditions. As a result, the packing density for experimental conditions involving high density ratios was greater than for experimental conditions involving low density ratios.

The study was exploratory in nature, by the fact that the writer failed to find studies directly related to the problem. This fact, in addition to the method selected for measuring performance, failed to permit investigation of the precise psychological processes involved in the study. These processes have been collectively referred to as the input component of the visual search task.

Definitions

Display Density. The number of items within the boundaries of the display. The density was expressed as the ratio of target items to non-target items.

Movement Speed. The rate of movement was the rotational speed of the display items. The movement was confined to the cue dimension.

Non-target. Any geometric shape used in the study with the exception of a square.

Non-target Similarity. The number of different items belonging to the non-target set. Similar displays contained only one type of non-target item. Non-similar displays contained an equal number of the four types of non-target items.

Packing Density. The degree to which the total display

area is filled with target and non-target items. The proximity of the display items was a function of the display area and the number of items present in the display.

Search Time. The time required by the subject to locate the target items for each trial was defined as search time.

Target. A geometric square.

Target Non-target Similarity. Similarity between target and non-targets was defined as the degree to which the non-target shapes resembled the target shape.

CHAPTER II

RELATED LITERATURE

The available literature concerning visual search can be classified into three categories depending on the type of variables investigated: display variables, performer variables, and task variables. The literature considered relevant for this study pertain to the factors assigned to the first category, that of display variables. The initial topics are presented to provide the general framework within which the present study was designed. The latter topics provide a review of the specific effects of the factors which were employed in the present study.

Display Factors Necessitating Visual Search

Visual search is initiated when information required from a visual display is not immediately available. The efficiency and ultimate success of the search process for each individual subject is determined to a large degree by the environmental factors present in the search field.

Gottsdanker (1960) referred to these factors as search determinants. They are as follows:

1. Interposition. The partial or complete blocking of the target symbol from the viewer.

2. Smallness. The relative size of the target symbol as compared to the size of the total display area.

3. Weakness. The relative contrast of the target

symbol as compared to that of the total display area.

4. Distortion. The perspective deformation of the target due to orientation of the target; or variations in density of the intervening medium.

5. Imbeddedness. The de-emphasis of target symbol contours by the use of strong inner contours; or the partial sharing of contours of target and non-target symbols.

6. Competition. The discrimination problem involving non-target symbols within the visual display containing the target symbol.

The determinant related to the present study was that of competition.

Visual Search Dimensions

The foremost problem in visual search tasks conducted through a display containing display items is that of discriminating target items from non-target items. Sleight (1952) investigated the discriminability of 21 geometric forms. The effectiveness of form discriminability was estimated from the sorting time required for each form. The attentional value of each form was determined by the order of priority of the subject's selection. Sleight concluded that the discriminability of any geometric form was not exclusively intrinsic to the form, but on extrinsic quality related to the total display characteristics.

The effectiveness of colour as a search dimension has been investigated by several authors. Green and Anderson

(1956) studied the effect of colour coding on visual search. When the subject knew in advance of the colour of the target, the search time was approximately proportional to the number of symbols with the same colour as the target. All display items were two digit numbers. The search time was dependent on the total number of items in the display in the conditions where the subject was not aware of the target colour prior to search. Search times through multicoloured displays were slightly longer than for uniformly coloured displays, in conditions of prior knowledge of target colour.

Smith (1962)(1963) used colour dimensions for displays varying in item numerosity from 20 to 100 items. The use of colour was related to a significant decrease in search time. Smith failed to detect a slower search time related to multicoloured displays than was reported by Green and Anderson. Smith (1962) suggested that the projection technique employed by Green and Anderson in their 1956 study led to a depth perception factor which slowed search rate.

Eriksen (1952) investigated the effect on search time of the number of dimensions on which the items differed. The dimensions used were hue, form, size, and brightness. Predicted values were calculated using a weighted geometric mean of the location times of the single component dimensions. The single dimension with the least mean search time was assigned a weight of two, and the dimension with the longer search time was given a weight of one. Hue was significantly

faster than the remaining three dimensions, and form was significantly faster than brightness and size.

Using an eye fixation measurement technique, Williams (1966) reported the effectiveness of three dimensions, size, shape, and colour, on visual search performance. He found that colour was the most effective dimensional cue. When two or three dimensions were specified prior to search, the subject generally fixated display items based on one of the available dimensions. The order of priority was colour, size, and shape. The efficiency of searching, as shown by the mean search times, also showed the superiority of colour codes. Mean search times were colour 7.6 seconds, size 16.4 seconds, and shape 20.7 seconds.

Thus, in visual displays, the number and type of search dimensions affect the search performance. In general, colour is the most effective dimension.

Measurement Involved in Visual Search Studies

The most common dependent variables used in visual search experiments were search time, scanning time, and errors. The task responses in various studies included visual location, pointing responses, verbal responses, card sorting, and item cancellations.

Search time was a measure of the total elapsed time from visual presentation of the display to completion of the identification response. The components involved in total search time were the initial delay at the start of the task,

the time spent on the visual search, target recognition time, organization time of the appropriate response, and the response time. The assumption made by investigators using search time as a dependent variable was that the fluctuations in search time due to independent variables such as density and background, would have the greatest effect upon visual search. The manipulating of visual variables should not influence the time involved in motor responses.

Neisser (1963) devised a method to determine the scanning rate (search rate) for each item of a display. The target position was plotted against the search time and a line was drawn using the least square method. The slope of this line was a measure of the time required to search an individual number. This measure, unaffected by the initial delay and some response factors of the search task, represented a relatively pure measurement of search rate.

In a study by Kaplan, Carvellas and Metlay (1966), the subject was photographed as he searched a display and cancelled the appropriate target items. Search rate was defined as the elapsed time between successive cancellations divided by the number of non-target items between the cancellations.

The use of search rate as the dependent variable in search tasks necessitated an organized search pattern (line by line) by the subject. This required a visual display so structured to produce this searching technique and the

co-operation of the subjects involved. The use of search time as a dependent variable, while not being as pure a measure, allowed freedom of search strategy by each subject. Studies that involved some form of random placement of symbols, used total search time as a measure of the time parameter.

A third measure of visual search performance was error score. The two types of errors common to visual search experiments were omission errors and commission errors. Neisser and Beller (1965) defined an omission error as the failure to locate a target item. A commission error was defined as an inappropriate response to a non-target item. In several visual search studies, the number of commission errors was relatively few (Brown and Chick, 1970, and Neisser et al, 1963).

Display Density and Visual Search

From a practical standpoint, it would seem reasonable to assume that the speed of detection of a target would be directly related to the numerosity of non-target items in the same visual display. McGill (1960) used background densities of 24, 48, 72, and 96 in a search task. The display items were three digit numbers randomly placed in an 18 inch square. The recorded search times were directly related to the number of alternatives (density). An increase in the number of alternatives caused an increase in the search time. The relationship between search time and

density was linear.

Green and Anderson (1956) found that the search time was proportional to the total number of items in the display. The subject's prior knowledge of the colour dimension shared by the target item reduced the search time. This reduced search time was proportional to the number of items (density) similar in colour to the target. Studies by Smith (1962) (1963) reported a similar relationship between density and search time.

Neisser (1963) compared the rate of scanning for a target letter over items two letters and six letters in width. The six letter item list took significantly longer to search than the two letter item list. This slower scanning rate was attributed to the larger number of letters (density) through which the search was conducted.

In a subsequent experiment, the search rate for six letter items was compared with four letter items. The four letter items were composed of the spacing of six letters by the use of two dashes between the letters. The longer scanning rate associated with the six letter item list convinced Neisser that the horizontal spread was not the critical factor in search, but rather the number of letters (density) in the display

The conclusion from the previous studies is that search time increases as the number of items in the display increases. The assumption underlying this observation is that

the display items lie within the same visual dimensions.

Target Non-target Similarity

Studies by Neisser (1963), Neisser, Novick, and Lazar (1963), Kaplan and Carvellas (1965), and Kaplan, Carvellas, and Metlay (1966) reported that the subject does not recognize the non-target items at a conscious level. Despite this lack of identification by the subject, the non-target items in the display did affect search performance.

Neisser (1963) found that target letters formed from straight line segments required a greater search time when imbedded in a display of similarly constructed letters than when they were imbedded in letters formed from curved line segments.

Gibson and Yonas (1966) used two conditions of background (non-target) confusion based on the curved or straight line segment letter format. The target letter was always a G. The low confusion background consisted of the angular letters L, K, V, M, X, and A. The high confusion background used the curvilinear letters B, Q, C, J, S, and R. The subjects were selected from second grade, fourth grade, sixth grade, and sophmore university students. A significantly longer search time for all groups was reported for high confusion backgrounds.

Kaplan, Yonas, and Shurcliff (1966) reported a similar effect of background confusion on visual search. The study employed a high and low level of visual as well as

acoustical confusability. The effect of acoustical confusability was not significant while the effect of visual confusability accounted for a significant difference in search time. It should be noted that this study used two target letters and required a motor response for specifying target discovery.

Gould and Peeples (1970) reported that the duration of eye fixations on objects within the visual display was directly related to the degree of similarity of that object to the target. In addition, the target non-target similarity was directly related to the probability of fixating any given object, and the sequence of fixating the objects.

The results derived from the previous studies support the conclusion that the degree of similarity between the targets and non-targets affects search performance. The greater the similarity between target and non-target items, the greater the search time.

Size of the Non-target Set

Gordon (1968) investigated the effects of four non-target items acting alone (homogeneous background) and then, acting in various combinations (heterogeneous background). The target symbol was an "a" and the background symbols used were "b", "c", "d", and "e". The backgrounds used in the study were each letter alone (background ratio of one to one), each possible paired combination (background ratio of one to two), and the four letters (background ratio of one

to four). A significant difference was demonstrated between the mean search rates for the three background ratios. The rate of search varied directly with the number of types of background letters present in the display.

A second experiment used nine cell matrices in place of letters as items. Four cells of each matrix were filled with a dot. The non-target matrices had no overlap cells with the target configuration. A third experiment used the same material with the exception of the inclusion of one overlap cell in each non-target matrix with the target matrix. The analysis of search rates revealed the same effect of background in both experiments. Increased heterogeneity of background slowed search rates. The differences between the condition means for the second and third experiments were not significant. Gordon hypothesized that homogeneity of background allowed a longer saccadic eye movement following a fixation. As background became more heterogeneous, the distance between successive fixations would decrease, thereby increasing search time.

In a further study, Gordon (1969) analysed eye movements of subjects performing a search task. He used non-target sets of one, two, and four irrelevant letters. Search time was significantly higher for the larger non-target sets. This increase in time was reported to be due to a significantly greater number of fixations, and a greater number of regressions (eye movements back over previously

searched material).

In highly structured displays (printed lines of alphabetic letters), the search performance was affected by the size of the non-target set. The larger the non-target set, the greater was the search time.

CHAPTER III

METHODS AND PROCEDURES

In reviewing visual search literature, a lack of information concerning search performance through fields containing elements of motion was revealed.

One category of motion could be classified as motion outside the cue dimension. An example of this type of motion would be translatory motion, or displacement, of display items which are being identified by some characteristic other than spatial location (e.g. colour, shape, or size). Measurement of dependent variables such as search time and commission errors, requires eye movement camera techniques.

A second category of motion could be classified as movement within the cue dimension. An example of this type of motion would be rotation of the display items which are being identified by shape. Measurement of the dependent variables such as search time and errors, can be made using the same techniques as used in static displays. For this reason, the present study investigated search performance in a visual display containing motion within the cue dimension.

Hypotheses

Hypotheses were formed ad hoc for the main effects of the independent variable, density, in both sections of the experiment.

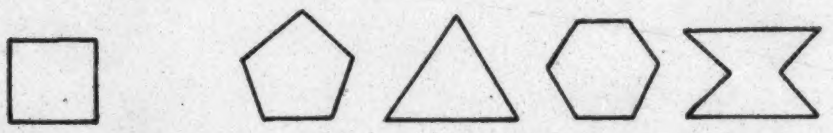
1. The effect of increasing the density ratio from one to four to one to twenty-four will result in an increase in search time.

2. The effect of increasing the size of the non-target set from one to four will result in an increase in search time.

Hypotheses were formed post hoc for all other main and interaction effects of the independent variables. The hypotheses were tested using an alpha level of .01.

Display Items

The single dimension on which discrimination of target and non-target could have occurred was shape. Dimensions such as size and hue were held constant. The target item was constant throughout all experimental conditions. The target shape was a square (Figure 1a). The four non-target shapes were closed geometric shapes having approximately the same subjective area as the square (Figure 1b).



a b

FIGURE 1 VISUAL DISPLAY ITEMS

Subjects

A group of 12 male subjects were randomly selected from a section of the freshman physical education class for the experiment. Two conditions were placed on the selection of the subject. The subject had normal or corrected normal vision, and he was available during the week the test was conducted. The range of ages was 7.0 years with a mean of 21.1 years.

Independent Variables

Three independent variables were selected for investigation in the primary section of the study. The second variable considered was that of density (item numerosity) represented by the target to non-target ratio. The two ratios used were one to four and one to twenty-four representing the low and high density conditions respectively.

The third variable selected was the size of the non-target set. Two sizes of non-target sets were used; a set of one non-target item (similar background) and a set of four non-target items (non-similar background).

The first variable selected for investigation was speed of movement. The three levels of movement speed used were static (0 revolutions per second), slow (approximately 1.4 revolutions per second), and fast (approximately 2.8 revolutions per second). The restriction on the fast speed was such that the rotation speed of the items was not great enough to cause shape distortion.

Experimental Conditions

The levels of the three factors were combined to yield 12 experimental conditions (Table I).

TABLE I

TREATMENT CONDITIONS

Condition	Movement	Density Ratio	Size of Non-target Set
1	Static	1:4	1
2	Slow	1:4	1
3	Fast	1:4	1
4	Static	1:4	4
5	Slow	1:4	4
6	Fast	1:4	4
7	Static	1:24	1
8	Slow	1:24	1
9	Fast	1:24	1
10	Static	1:24	4
11	Slow	1:24	4
12	Fast	1:24	4

Preparation of Treatment Conditions

For each of the experimental conditions, four segments (representing the four replications per condition) were prepared. The location and orientation of the display items w were random within the constraints of the search field. The size of the search field and the display items were constant across all conditions and replications. As a result, the packing density for the high density conditions was greater than for the low density conditions.

The low density conditions were of ten second duration and the high density conditions were 15 seconds in duration. The cost of producing the experimental conditions necessitated conservation of film. It was predicted prior to filming, that ten seconds would be an adequate time for the subjects to locate all four targets under the low density conditions. Upon completion of the experiment, it was noted that all subjects completed the low density conditions without incurring any omission errors.

Preparation of the Display Film

The number of film segments produced was 48, determined by the two density levels, two background levels, three movement speeds, and four replications. The 48 film segments were then spliced in random order. The order was random with the following constraints on randomness; that no more than two segments of identical density and background, movement speed, or replication could occur in succession.

The display film was then constructed with 12 feet (30 seconds) of yellow leader between each of the 48 film segments. The film was 34 minutes in length, consisting of 24 segments of ten seconds and 24 segments of 15 seconds. The film was projected at a rate of 16 frames per second.

Double perforation film was used to permit the film to be shown in reverse order. As a further precaution against an order of presentation effect, the film was shown in reverse order to six of the twelve subjects. A description of the construction of the film is found in Appendix A.

Apparatus

The sequential timing apparatus (SETA) consisted of three components; a marking pen, a stepping relay, and eight Standard Electric chronoscopes.

The marking pen consisted of a pen cartridge mounted inside a copper pen barrel (Figure 2). A micro-switch was mounted on the upper end of the pen barrel. The micro-switch was wired to the stepping relay component of SETA.

Eight Standard Electric chronoscopes were wired in phase to the stepping relay. The time to locate each target item was displayed on the chronoscopes. A second micro-switch was used by the investigator to start the first chronoscope on each trial. Simplified wiring diagrams for the apparatus appear in Appendix B.

The viewing apparatus consisted of a Kodak 16 mm. projector and a rear view projection screen. A plate glass

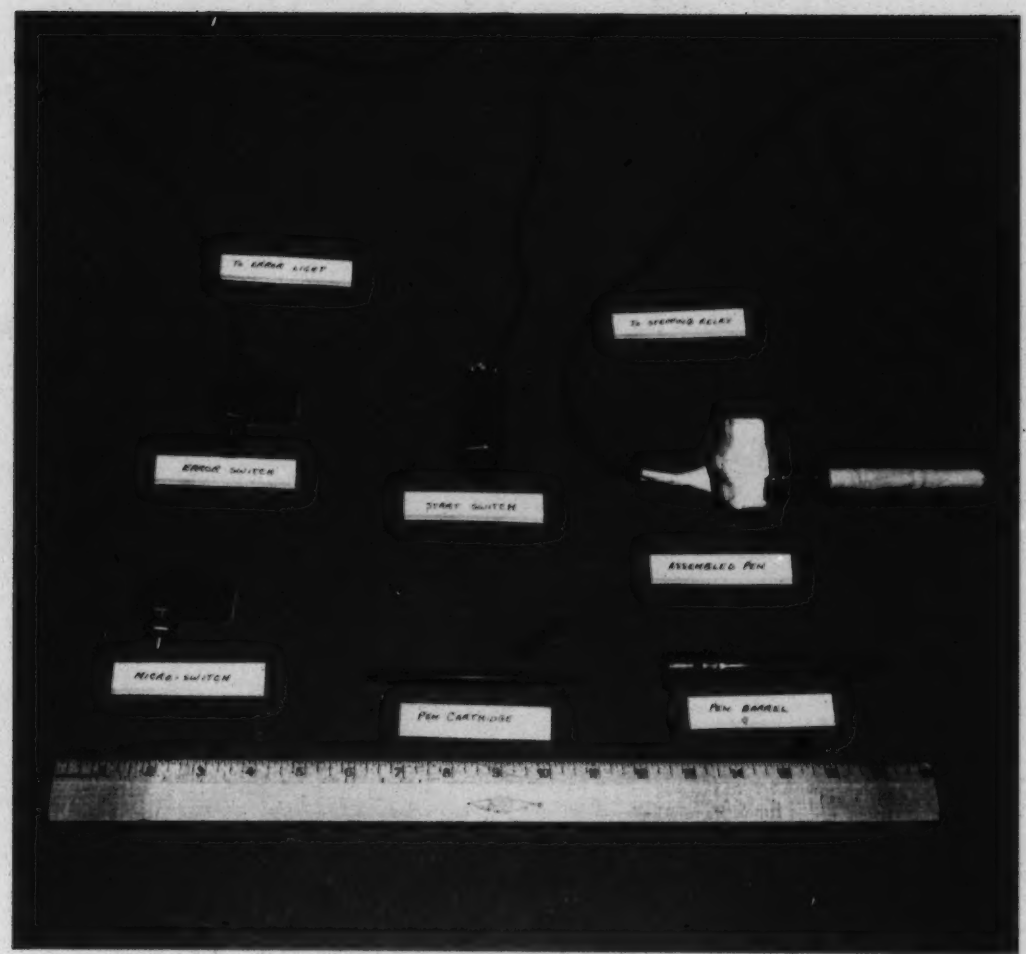


FIGURE 2 MARKING PEN ASSEMBLY

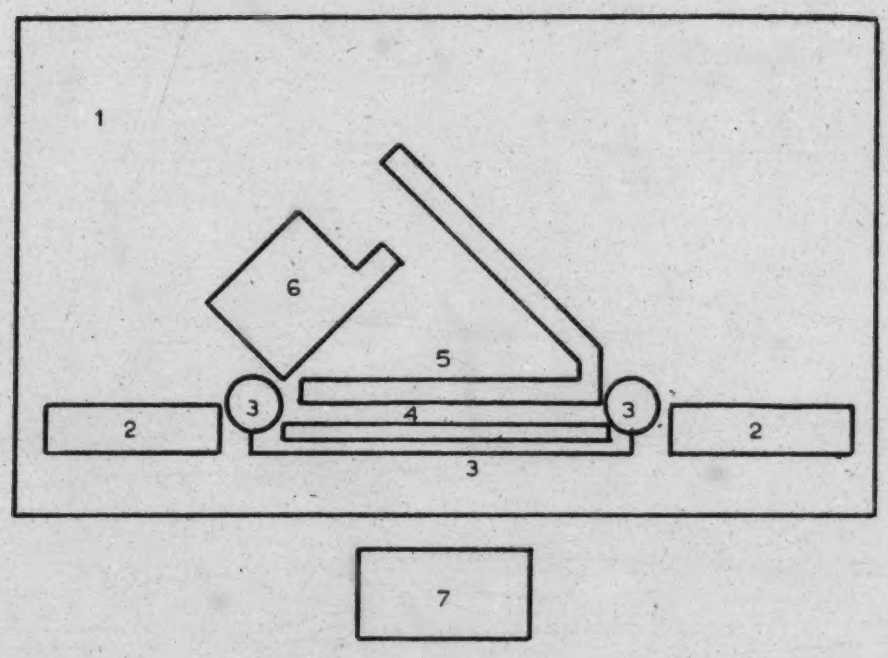
barrier was situated directly in front of the projection screen and a sliding plastic sheet was mounted directly on the plate glass. The plate glass barrier prevented any damage to the projection screen as the subject located and marked the target items. At the end of each trial, the plastic sheet was moved to prevent confusion on the subject's part as to what targets had been located (Figure 3).

The viewing apparatus was mounted on a table and a black wooden screen was constructed to block all the apparatus from the view of the subject with the exception of the viewing aperture. The stepping relay and the chronoscope components of SETA were located outside the testing room. The investigator observed the subject during the course of the experiment through a one-way mirror mounted in the wall of the testing room directly behind the subject.

The Dependent Variable

Previous investigators have made use of three search performance parameters. The most common measure of performance was time. Neisser (1963) employed a measure of time referred to as scan time, which eliminated the initial reaction time (see Chapter II). Smith (1962)(1963) and Promisel (1961) used search time which included the response time. The present study used the total time to locate and mark the four targets (squares) present in each stimulus trial as the dependent variable.

A second measure of search performance was the frequency



1. Table
2. Blind
3. Plastic Sheeting
4. Plate Glass
5. Rear View Projection Screen
6. Film Projector
7. Subject's Seat

FIGURE 3 VIEWING APPARATUS

of omission errors. An omission error was defined as the failure to locate and mark a target item present in the stimulus trial. The present study employed a limited time period of presentation; e.g. 10 seconds and 15 seconds for low and high density conditions respectively. As a result, the occurrence of omission errors was possible. The performance time for the stimulus trials on which omission errors occurred was the total time the presentation was available to the subject.

The third measure of search performance was the frequency of commission errors. A commission error was defined as the occurrence of a target response to a non-target item. For adult subjects, this parameter could be used as an indicator of the speed accuracy set employed by the subject. The frequency of commission errors was expected to be relatively low and, as a result, would not be partitioned out in the analysis. Any subject committing more than one per cent commission errors was considered a hostile subject, and his data eliminated from the experiment.

Procedure

The subject was seated in front of the viewing aperture and the set of instructions were read (Appendix C). The subject was familiarized with the operation of the marking pen and the moveable plastic sheet. The subject was instructed to locate the targets (squares) and mark them as quickly and accurately as possible. Upon completion of the

instructions, the projector was started and the investigator left the testing room and took his seat behind the one-way mirror.

After the first 24 trials, a short three to five minute rest was taken. The last 24 trials were then completed. During the 30 second rests between trials, the performance times were recorded by the investigator on coded data sheets.

Experimental Design

The design underlying the experiment was that of a treatment by subjects. Each subject received four trials under each of the 12 experimental conditions.

Statistical Model

The statistical model used was a three by two by two by four by twelve factorial with one entry per cell. The model consisted of three movement speeds, two levels of density, and two levels of size of non-target set. The four trials for each subject under each experimental condition were treated as a replication factor for diagnostic purposes. The 12 subjects were treated as a repetition factor for diagnostic purposes.

The levels of density, background, and movement speed were considered fixed. The levels of repetition and replication were considered random. The resulting model was a mixed model with complete blocks.

The secondary phase of the experiment investigated the effect of the four different non-target items on visual

search performance. Only the search times secured under similar non-target set conditions were used. The resulting model was that of a three by two by four by twelve. The model consisted of three movement speeds, two levels of density, four types of background, and 12 repetitions (subjects). The repetition levels were considered random.

CHAPTER IV

RESULTS AND DISCUSSION

The analysis was divided into two segments. The primary analysis involved the following factors: movement speed (m), density (d), size of the non-target set (n), replications (r), and subjects (s). The secondary analysis involved the following factors: movement speed (m), density (d), type of background item (b), and subjects (s).

Analysis of the Data

The data was entered and verified on IBM data cards. The data was processed using a Fortran IV program for an n way analysis of variance. A test on means followed. The .01 level of significance was required for the rejection of all ad hoc and post hoc hypotheses. Post hoc tests of hypotheses were performed upon securing significant interactions. The .005 level of significance ( ) was required for rejection of all hypotheses. The test on means used was Duncan's New Multiple Range Test.

Results of the Primary Analysis

A five way analysis of variance was performed on the search times under the 12 experimental conditions.. The results of the analysis are found in Table II. The complete analysis is reported in Appendix D. The five hypotheses formed concerning the main effects were:

TABLE II

PRIMARY ANALYSIS
ANALYSIS OF VARIANCE OF SEARCH TIMES (SEC.) BASED ON THE TIME REQUIRED TO LOCATE FOUR TARGETS

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
M (movement)	2	70.30	19.31 *
D (density)	1	780.46	123.88 *
M X D	2	43.41	9.71 *
N (non-target set)	1	48.31	13.16 *
M X N	2	39.71	11.78 *
D X N	1	0.02	0.00
M X D X N	2	8.61	2.04
C (replications)	3	59.27	14.05 *
M X R	6	14.73	4.05 *
S (subjects)	11	30.83	7.31 *
M X R X S	66	3.64	0.86
D X R X S	33	6.30	1.49
M X D X R X S	66	4.47	1.06
N X R X S	33	3.67	0.87
M X N X R X S	66	3.37	0.80
D X N X R X S	33	4.29	1.02
Error	66	4.22	

Critical F value for df 2,66 at .01 level = 4.96
" " " " " 1,33 " " " = 7.48
" " " " " 3,66 " " " = 4.11
" " " " " 6,66 " " " = 3.10
" " " " " 11,66 " " " = 2.54

* Significant at the .01 level

H_1: There would be no effect caused by movement speed on search time.

H_2: An increase in the density of the display would cause an increase in search time.

H_3: An increase in the size of the non-target set would cause an increase in search times.

H_4: Search times would decrease over replications.

H_5: The search times of the subjects would be significantly different.

The first hypothesis concerning movement speed was stated in null form as the effect of movement speed was exploratory in nature. A summary of the tests of significance of the first and second order interactions are found in Table III.

Effect of Movement Speed

The effect of movement speed, the interaction of movement speed and density, the interactions of movement speed and size of the non-target set, and the interaction of movement speed and replications were all significant (p .01) as reported in Table II.

The movement speed by density interaction was significant. The resulting F ratio was 9.71 (p .01). The results of a Duncan's New Multiple Range Test applied to the differences between the mean search times is reported in Table IV. Under low density conditions, the effect of movement speed on mean search time was not significant.

TABLE III

RESULTS OF TESTS OF SIGNIFICANCE
ON THE POST HOC HYPOTHESES

Hypotheses	Result of F Test	Probability
$^2_{md} = 0$	null rejected	.01
$^2_{mn} = 0$	null rejected	.01
$^2_{dn} = 0$	null accepted	-
$^2_{mdn} = 0$	null accepted	-
$^2_{mr} = 0$	null rejected	.01
$^2_{nr} = 0$	null accepted	-
$^2_{dr} = 0$	null rejected	.01

TABLE IV

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED BETWEEN K=6
MEANS FOR MOVEMENT SPEED BY DENSITY INTERACTION

	Low Density Static	Low Density Fast	Low Density Slow	High Density Fast	High Density Static	High Density Slow	Shortest Sig. Ranges
Means	3.07	3.12	3.36	4.54	5.37	6.67	
3.07		.05	.29	1.47*	2.30*	3.60*	.90
3.12			.24	1.42*	2.25*	3.55*	.94
3.36				1.18*	2.01*	3.31*	.96
4.54					.83	1.30*	.98
5.37						1.30*	1.00

* Significant at the .005 level

Under high density conditions, the slow movement speed produced significantly slower mean search times than the static or fast movement speeds ($p < .003$).

The significant density by movement speed interaction is graphically represented in Figure 4.

The movement speed by size of non-target interaction was significant. The resulting F ratio was 11.78 ($p < .01$). The results of a Duncan's New Multiple Range Test applied to the differences between the mean search times is reported in Table V. Mean search times under non-similar target sets and slow movement speed were significantly slower ($p < .001$).

The significant movement speed by size of non-target set interaction is graphically represented in Figure 5.

The movement speed by replications interaction was significant. The resulting F ratio was 4.05 ($p < .01$). The results of a Duncan's New Multiple Range Test applied to the difference between the mean search times is reported in Table VI. The significant movement speed by replications interaction is graphically represented in Figure 6.

Effect of Density

A significant difference was found between the two levels of density. The resulting F ratio was 123.88 ($p < .01$).

Effect of Background

A significant difference was found between the two levels of non-target sets. The resulting F ratio was 13.16 ($p < .01$).

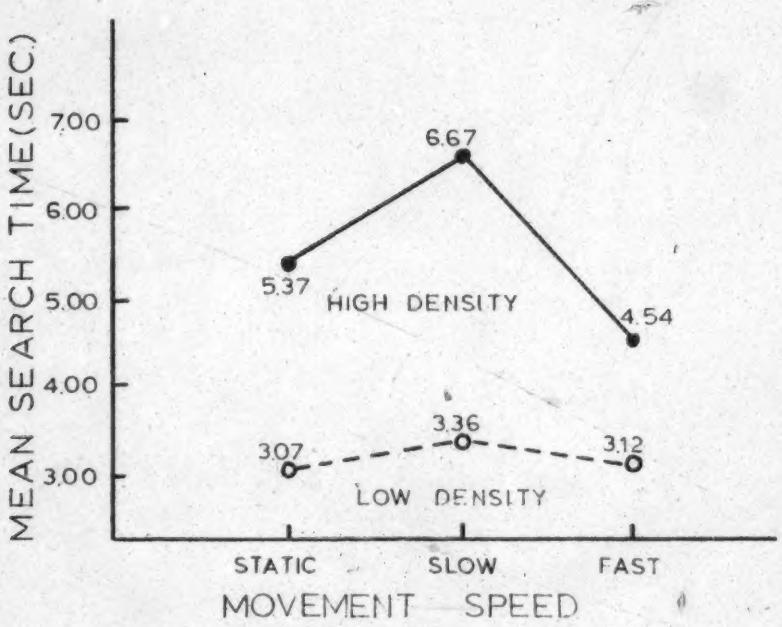


FIGURE 4

MOVEMENT SPEED VS MEAN SEARCH TIME FOR TWO LEVELS OF DENSITY

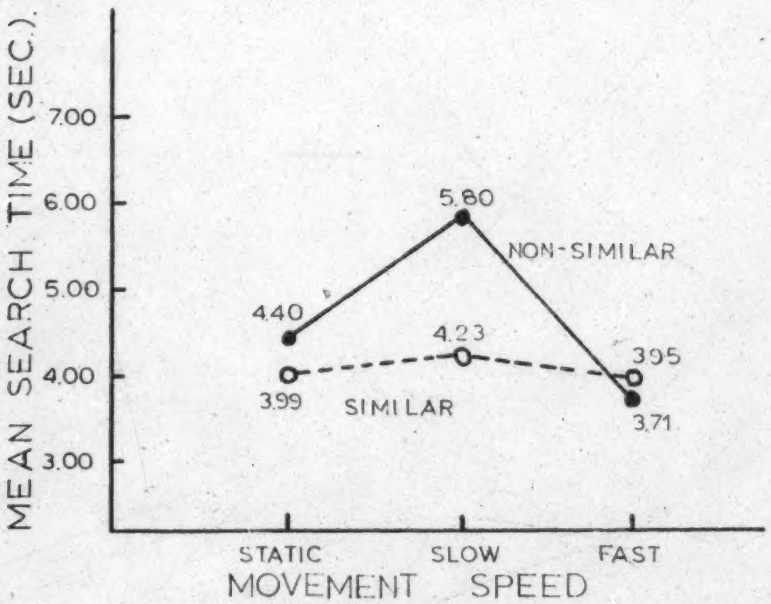


FIGURE 5

MOVEMENT SPEED VS MEAN SEARCH TIME FOR TWO SIZES OF NON-TARGET SETS

TABLE V

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED BETWEEN K= 6 MEANS FOR MOVEMENT SPEED BY SIZE OF NON-TARGET SET INTERACTION

	Non-Similar Fast	Similar Fast	Similar Static	Similar Slow	Non-Similar Static	Non-Similar Slow	Shortest Significant Ranges
Means	3.71	3.95	3.99	4.23	4.40	5.80	
3.71		.24	.28	.52	.69	2.09*	.78
3.95			.05	.28	.45	1.85*	.81
3.99				.24	.41	1.81*	.83
4.23					.17	1.57*	.85
4.40						1.40*	.86

* Significant at the .005 level

TABLE VI

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED BETWEEN K = 12
MEANS FOR MOVEMENT SPEED BY REPLICATION INTERACTION

	Rep 4 Fast	Rep 4 Static	Rep 3 Fast	Rep 3 Slow	Rep 1 Fast	Rep 3 Static	Rep 1 Static	Rep 4 Slow	Rep 2 Static	Rep 2 Fast	Rep 2 Slow	Rep 1 Slow	Shortest Sig. Ranges
Means	2.81	3.48	3.90	3.91	3.98	4.17	4.52	4.57	4.60	4.64	5.32	6.26	
2.81		.67	1.09	1.10	1.17	1.36*	1.71*	1.76*	1.79*	1.83*	2.51*	3.45*	1.23
3.48			.42	.43	.50	.69	1.04	1.09	1.12	1.16	1.84*	2.78*	1.28
3.90				.01	.08	.27	.62	.67	.70	.74	1.42*	2.36*	1.32
3.91					.07	.26	.61	.66	.69	.73	1.41*	2.35*	1.34
3.98						.19	.54	.59	.62	.66	1.34	2.28*	1.36
4.17							.35	.40	.43	.47	1.15	2.09*	1.38
4.52								.05	.08	.12	.80	1.74*	1.39
4.57									.03	.07	.75	1.69*	1.40
4.60										.04	.72	1.66*	1.41
4.64											.68	1.62*	1.42
5.32												.94	1.43

* Significant at the .005 level

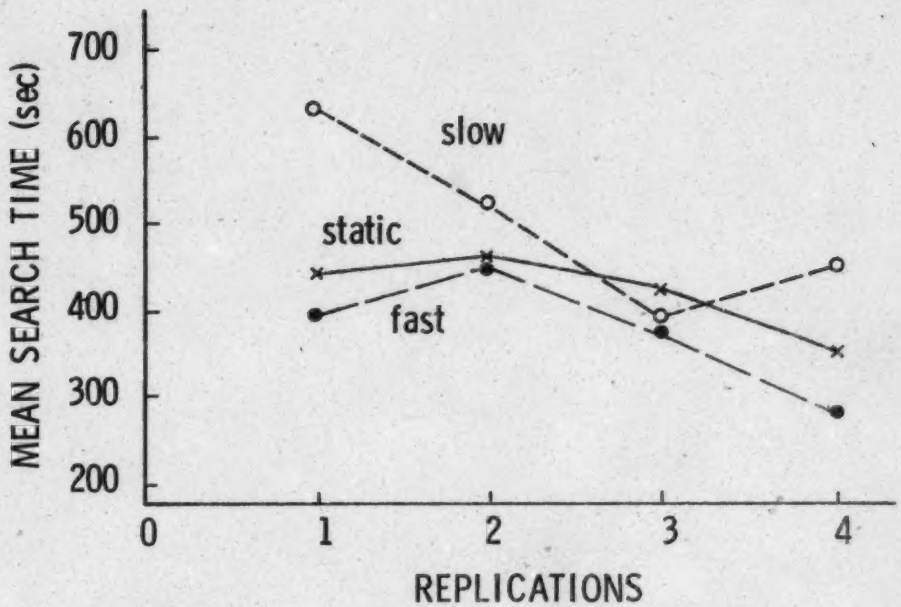


FIGURE 6

REPLICATIONS VS MEAN SEARCH TIME FOR THREE MOVEMENT SPEEDS INTERACTION

Effect of Replication

A significant difference was found between the four replications. The resulting F ratio was 14.05 (p .01). The results of the Duncan's New Multiple Range Test applied to the differences between the four repetition means showed the means of the first and second replication were significantly larger than the means of the third and fourth replications (p .005). See Table VII.

Effect of Subjects

The effect of subjects was significant. The resulting F ratio was 7.31 (p .01). No subject by condition interaction was significant.

Results of the Secondary Analysis

A four way analysis of variance was performed on the search times under 24 experimental conditions. The results of the complete analysis are found in Table VIII. The four hypotheses formed concerning the main effects were:

H_1: There would be no effect caused by movement speed on search time.

H_2: An increase in the density of the display would cause an increase in search time.

H_3: The types of non-target symbol used in a display would cause differences in search times.

H_4: The search times of subjects would be significantly different.

TABLE VII

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED BETWEEN K=4 MEANS FOR REPLICATIONS

	Rep. 4	Rep. 3	Rep. 2	Rep. 1	Shortest Significant Ranges
Means	3.62	3.99	4.85	4.95	
3.62		.37	1.23*	1.33*	.70
3.99			.86*	.96*	.73
4.85				.10	.75

* Significant at the .005 level

TABLE VIII

SECONDARY ANALYSIS
ANALYSIS OF VARIANCE OF SEARCH TIMES (SEC.) BASED ON THE TIME REQUIRED TO LOCATE FOUR TARGETS

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
M (movement)	2	.25	.80
D (density)	1	10.66	21.40*
M X D	2	.55	1.83
B (type of background)	3	1.88	6.33*
M X B	6	.26	.81
D X B	3	.70	2.18
M X D X B	6	.22	.66
S (subjects)	11	1.45	4.40*
M X S	22	.31	.94
D X S	11	.46	1.40
M X D X S	22	.35	1.06
B X S	33	.32	.99
M X B X S	66	.31	.96
D X B X S	33	.28	.85
Error	66	.33	

Critical F Value for df 1,11 at the .01 level = 9.65
" " " " " 3,33 " " " " = 4.45
" " " " " 11,66 " " " " = 2.54

* Significant at the .01 level

The first hypothesis concerning movement speed was stated in null form as the direction of the effect of movement speed or search time was not known and was therefore exploratory in nature.

Effect of Density

A significant difference was found between the two levels of density. The resulting F ratio was 21.4 ($p < .01$).

Effect of Type of Non-Target Items

A significant difference was found between the four types of background items. The resulting F ratio was 6.33 ($p < .01$). The results of the Duncan's New Multiple Range Test applied to the differences between the four non-target items showed the means for each type of non-target figure were significantly different. See Table IX.

Effect of Subjects

The effect of subjects was significant. The resulting F ratio was 4.40 ($p < .01$). No subject by condition interaction was significant.

Discussion

The visual search test employed in the present study involved visual search strategy as well as individual eye movements. The displays constructed did not present any obvious organizational cues to assist the subjects to select an optimal search strategy. In addition, the test included a perceptual motor response. The response time was included

TABLE IX

DUNCAN'S NEW MULTIPLE RANGE TESTS APPLIED BETWEEN K= 4 MEANS FOR FOUR TYPES OF NON-TARGET ITEMS

					Shortest Significant Ranges
Means	3.25	3.67	4.48	4.81	
3.25		.42*	1.23*	1.56*	.20
3.67			.81*	1.14*	.21
4.48				.33*	.21

* Significant at the .005 level

in the search time, but was balanced across all experimental conditions.

The search times were derived from the total time required to locate all targets. Fitts and Posner (1960) suggested that performance may vary on two parameters, speed and accuracy. Throughout the experiment, no commission errors occurred. This suggested that the subjects selected a search strategy weighted toward accuracy rather than speed. The lack of commission errors may, however, be a result of error correction during the motor response in locating the targets. It would appear that eye movement measurements would be required to resolve this issue.

The number of omission errors occurring during the experiment was 21. This represented less than one per cent of the total number of targets (2,304). The relatively small number of omission errors was not sufficient to allow separate analysis. Three targets were omitted under the low density conditions and 18 targets were omitted under high density conditions. The occurrence of omission errors was not unexpected, as each condition was presented for a fixed length of time, e.g. low density conditions for ten seconds and high density conditions for fifteen seconds. The low percentage error rates suggest the test was well within the capabilities of the group being tested.

Fitts and Posner (1969) suggest that the variables important to the understanding of performance will have the same directional effect across all human performers,

irrespective of magnitude. The subjects involved in the present study were a relatively homogeneous group in relation to educational achievement. The subjects' performances were significantly different from each other. The lack of significant subject by condition interaction demonstrated that the effects of the independent variables under investigation were not significantly different for the individual subjects.

The secondary analysis was performed to ascertain the effects of the specific non-target shapes used in the investigation. Gould and Peeples (1970) reported a significant increase in the duration of eye fixations and the probability of fixating objects with an increase in target non-target similarity. The result of the means test applied to the four types of non-target items used in the present investigation indicated each type of item caused a significant difference in the search performance of the subjects. This result was interpreted as indicating that four degrees of target non-target similarity were selected.

An important result of the secondary analysis was the failure of any of the type of non-target items by condition interaction to reach significance. This result supports the contention that the effect of target non-target similarity did not have a significantly confounding effect across the other levels of the independent variables; density and movement speed in the primary analysis.

The significant movement speed by density interaction demonstrates the effect of density within the search field on search times. Search times under high density conditions were significantly larger than under low density conditions, irrespective of movement speed. McGill (1960) stated that high density conditions act as a magnifier of perceptual differences. Under the high density condition, the slow movement speed produced search times which were significantly slower than under static or fast movement speeds. The introduction of slow movement into the visual display (high density) appeared to have the effect of increasing the complexity of the display. It is possible that this increased complexity could cause an increase in the number of fixations, due to the increased uncertainty in the peripheral retinal areas. It is also possible that the duration of the fixations would increase because of the greater difficulty in the identification and/or selection phases of the fixation. The measure of search time used in this study does not provide the information required to determine which of these occurred.

The effect of the size of the non-target set was only significant when viewed as an interaction with movement speed. This result is in disagreement with the results reported by Gordon (1968)(1969). The static movement speed condition is directly comparable to the studies by Gordon. The present study employed random placement of items within the visual display as well as random item orientation.

The randomization of spatial placement appeared to destroy any beneficial effects a smaller non-target set had on visual search performance. Gordon's studies employed organized matrices of items with constant item orientation.

The search times under slow movement speed with a non-similar target set were significantly larger than all other movement speed and non-target set conditions. The additional complexity of slow movement speed and size of non-target set appeared to have an additive effect on the difficulty of the search task.

The introduction of slow movement in combination with the effect of high density, or non-similar non-target sets, reduces significantly the visual search performance.

The effect of slow movement would appear to make the selection phase of the fixation more difficult, and hence of longer duration. In addition, the time required to reject a non-target would be greater because of the increased uncertainty created by the larger non-target set.

The effect of the fast movement speed conditions was not significantly different from that of the static conditions. The fast movement speeds appeared to accentuate differences between the display items. Williams (1966), using colour as a search dimension, hypothesized that the colour created a perceptual structure within the display which the subject searched. The fast movement speeds may have created such a perceptual structure.

If this was true, the search times under fast movement

speeds should be significantly faster than the search times under the static conditions. The fast movement speed also would create a more difficult recognition task. Thus, the increase in performance gained by the perceptual structuring of the display (therefore fewer fixations) may be reduced by the longer recognition time (therefore fixations of longer duration). It would require the measurement of eye fixations to resolve this issue.

Neisser and Lazar (1964) reported a significant decrease in search time over 23 practice sessions. Neisser (1963) also reported the significant effect of practice over 31 practice sessions. Gordon (1968) found a similar rapid decrease in search time over ten trials. The greatest decrease in search time occurred during the early trials in all studies. In all three studies, the display items were placed in a highly predictable pattern, e.g. row by row matrices. Thus, familiarity with the mechanics of the search task, the organizational constraints of the display, and the display items results in rapid improvement in search performance.

The present investigation attempted to balance the replication (practice) effect across the 12 experimental conditions. In addition, two orders of presentation were used to further attempt to balance the replication effect. The effect of practice was significant, in agreement with the previously reported studies. The general trend was as predicted, with the search times of the first trial being

significantly longer than the search times of the last trial.

The movement speed by replication interaction was also significant. The effect of replications across the static and fast movement speeds was not significant. However, mean search times for slow movement speeds showed significant decreases across the first, second, and third replications. The significant practice effect for the slow movement speed suggests that search through these types of fields constitutes a signficantly more difficult search task initially. It would appear that a study involving more replications would be required to determine if search performance under the slow movement condition would, in time, be equivalent to search under the fast and static movement conditions.

The trend of the effect of replications (practice) was in accord with the current literature. The present study represented one practice session as compared to the more numerous practice sessions investigated in the Gordon (1968), Neisser (1963), and Neisser and Lazar (1964) studies, and as such makes the comparisons difficult.

The search task described by Enoch (1960) involved two phases, an orientation phase and a specific search phase. Enoch hypothesized that general information concerning the display was selected during the orientation phase. The specific search phase consisted of a pattern of individual eye movements influenced by peripheral factors. The eye movements consist of fixations and saccadic movements.

Williams (1966) suggested that two activities, identification of the foveally imaged object and acquisition of the next fixation point from the peripheral information, take place during a fixation. Total search time would, therefore, depend on the number of fixations and the duration of the fixations that occur.

McGill (1960), Green and Anderson (1956), and Smith (1962)(1963) reported increased search time as the display density increased. The present study was in agreement with the results of these studies. The effect was significant across the three movement speeds under investigation. Miller (1969) commented on the tunnel vision effect induced by complex displays. This effect resulted in a reduced efficiency in selecting information from the peripheral retina and, thereby, shortened interfixation distances. The shorter interfixation distances, in turn, result in more fixations being required to provide the necessary coverage of the display for adequate search performance. It is possible that a greater number of fixations occurred under the high density condition of the present study, which accounted for the significantly greater search times.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to investigate the effect of movement in the cue dimension on visual search performance. The design was a treatment by subject factorial, complete block, mixed model with repeated measures. The subjects were 12 students enrolled in the Introductory Physical Education Course at the University of Alberta, whose mean age was 21.1 years.

Three independent variables were selected; movement speed, density, and size of the non-target set. The three levels of movement speed selected were static, slow, and fast. Two levels of density and two levels of non-target set were used. The levels of the three independent variables were combined to form 12 experimental conditions. Each subject received four trials under each of the 12 experimental conditions.

The conditions were constructed on film and presented to the subject using a rear view projection technique. Each condition contained four target items randomly located among the non-target items. The time to locate each of the four targets was recorded using the SETA apparatus and eight electric chronoscopes.

Performance was evaluated from two aspects; speed of search, and accuracy. Commission and omission errors were

recorded during the experiment.

The primary analysis involved three major hypotheses. The first hypothesis stated that increasing the movement speed in the cue dimension would have no effect on search time. The second hypothesis stated that the effect on increasing the density ratio of the display items from one to four to one to twenty-four would result in an increase in search time. The third hypothesis stated that the effect of increasing the non-target set from one to four would result in an increase in search time. The hypotheses concerning replication and subject effects were formed for diagnostic purposes.

The secondary analysis involved three major hypotheses. The first stated that there would be no effect on search time caused by movement speed. The second hypothesis stated that an increase in density would cause an increase in search time. The third hypothesis stated that the type of non-target symbol used would not affect search time.

The effect of slow movement speed within the visual display caused significantly longer search times under conditions of high density and under the condition of high density non-similar background. The effect of fast movement speed was not significantly different from the static condition. The effect of increasing the density ratio caused a significant increase in search times in both analyses.

The effect of increasing the size of the non-target

set caused an increase in search time only under conditions of slow movement speed.

The effect of the four types of non-target items caused a significant difference in search times. No interactions under the secondary analysis were significant.

Conclusions

On the basis of the results obtained and within the limitations of the design and the techniques of data collection, the following conclusions were drawn from the primary analysis.

1. The effect of movement speed in the cue dimension in a visual search task causes an increase in visual search times under conditions of slow movement speed and high display density, and under conditions of slow movement speed and non-similar background.

2. The effect of density causes an increase in search times across three movement speeds and two sizes of non-target sets.

3. Increasing the size of the non-target set has its greatest effect when viewed as an interaction affected by increases in item density and slow item speeds.

As a result of this investigation, a further study into the effects of motion outside the cue dimension on visual search performance, is indicated. Since this study would involve translatory motion (item displacement), it would appear that eye movement recordings would be required to measure search performance.

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APPENDIX A

FILM CONSTRUCTION

The display items (geometric forms) were constructed on white cardboard. The items were glued to the ends of four inch nails. Two masonite boards were mounted two inches apart to a table. A random series of holes were drilled through the boards and small metal sleeves were mounted in each hole. A black cloth was fastened to the outside face of one of the masonite boards. The nails with the target items were placed through the holes in the board.

Small pulleys (Mechano) were secured to the ends of each of the nails. The pulleys were threaded with plastic belting (alpha wire casing) and attached to the drive shaft of a small two speed motor. The motor was started and the display items were rotated. The direction of the rotation was controlled by the placement of the plastic belting. An attempt was made to make the direction of rotation as random as possible.

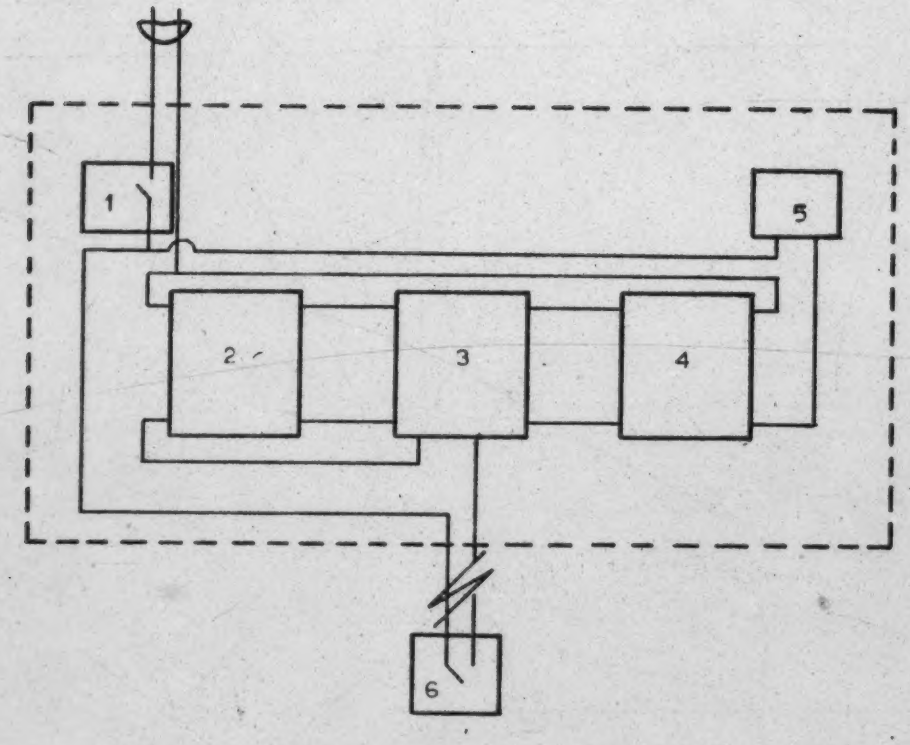
The camera was mounted on a stand directly in front of the display board. Each of the low density conditions were then photographed for ten seconds. Between the filming of each condition, the display items were re-arranged to prevent a constant pattern from occurring on all segments. For static displays, the item orientation was altered as well as the item positions between the filming of each segment.

The high density conditions involved 100 display items. To film these segments, one quarter of the display board was

loaded with 25 display items. A three quarter blackout template was mounted in front of the camera and the segment was filmed. The film was then rewound to the initial starting position, and the display items randomly replaced. The blackout template was reversed and the segment was filmed. This procedure was repeated until all four quadrants on the film were exposed. The segments were 15 seconds in duration.

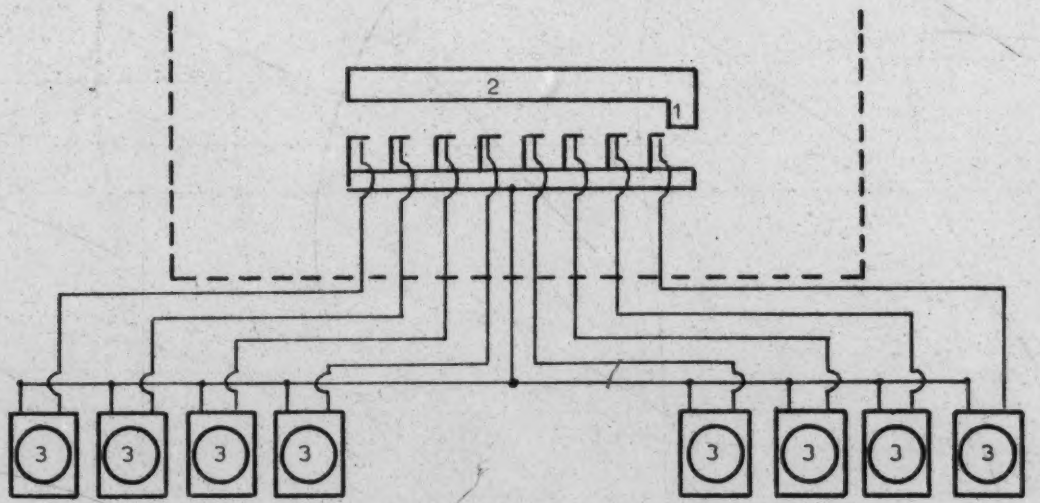
Prior to filming each segment, a code chart was filmed to assist in identification of the experimental conditions. The film was processed and the segments cut and arranged in the presentation order. Leader film (equivalent of 30 seconds) was spliced between each film segment and at the start and end of the film. Double perforated film was used to allow the film to be shown in two orders e.g. start to end, and end to start.

APPENDIX B



1. On-Off Switch
2. Relay Control
3. Relay Counter
4. Relay Reset
5. Reset Switch
6. Marking Pen Microswitch

FIGURE 7 SETA - RELAY COMPONENT



1. Contact Point
2. Contact Ring
3. Standard Electric Chronoscope

FIGURE 8 SETA - TIMING COMPONENT

APPENDIX C

INSTRUCTIONS TO SUBJECTS

The study you are participating in is concerned with visual search performance. In many activities in which you participate, you are required to select information from your environment in order to make the proper response. This study is attempting to investigate some of the factors which affect your selection.

The displays that you will search through will be presented on the screen directly in front of you. Between each trial, there will be a 30 second pause during which time your scores will be recorded. During this time, you will turn the reel to your right, which will move the plastic sheeting. It is only necessary to move the sheeting until the pen marks are no longer visible to you. Try moving the sheeting.

In front of you is the pen you will use to mark the targets you have located. Try marking with the pen. You notice that there is a small clicking noise when you depress the pen. This enables me to record your performance time.

The object of your search is to locate four targets which will be geometric squares. There will be other geometric shapes in the display, but your task is simply to locate and mark each of the squares.

Here is a practice sheet. Attempt to locate and mark the targets as quickly and accurately as possible.

The time for the entire test is approximately 35

minutes. We will break for a few minutes half way through the test. Do you have any questions?

Remember, work as quickly and accurately as possible.

APPENDIX D

TABLE X

PRIMARY ANALYSIS

COMPLETE ANALYSIS OF VARIANCE OF SEARCH TIMES (SEC.) BASED ON THE TIME REQUIRED TO LOCATE FOUR TARGETS

Source of Variation	Degrees of Freedom	Mean Square	F Ratio
M (movement)	2	70.30	19.31*
D (density)	1	780.46	123.88*
M X D	2	43.41	9.71*
N (non-target set)	1	48.31	13.16*
M X N	2	39.71	11.78*
D X N	1	0.02	0.00
M X D X N	2	8.61	2.04
R (replication)	3	59.27	14.05*
M X R	6	14.73	4.05*
D X R	3	26.25	4.17
M X D X R	6	10.40	2.33
N X R	3	4.31	1.17
M X N X R	6	1.65	0.49
D X N X R	3	10.20	2.38
M X D X N X R	6	6.25	1.48
S (subjects)	11	30.83	7.31*
M X S	22	4.03	1.11
D X S	11	8.00	1.27
M X D X S	22	3.85	0.86
N X S	11	8.22	2.24
M X N X S	22	4.06	1.20
D X N X S	11	7.22	1.68
M X D X N X S	22	3.62	0.86
R X S	33	4.28	1.02
M X R X S	66	3.64	0.86
D X R X S	33	6.30	1.49
M X D X R X S	66	4.47	1.06
N X R X S	33	3.67	0.87
M X N X R X S	66	3.37	0.80
D X N X R X S	33	4.29	1.02
Error	66	4.22	

* Significant at the .01 level